Forensic Engineering

Advancing Tunneling - the Victorian Engineering Management Legacy

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Corresponding Author:	Vikki Edmondson, BSc MEng Northumbria University Newcastle Upon Tyne, UNITED KINGDOM
Corresponding Author Secondary Information:	
Corresponding Author's Institution:	Northumbria University
Corresponding Author's Secondary Institution:	
First Author:	Vikki Edmondson, BSc MEng
First Author Secondary Information:	
Order of Authors:	Vikki Edmondson, BSc MEng
	Fred Sherrat, PhD
	Richard Roff
	Andy Levett
Order of Authors Secondary Information:	
Abstract:	The Victorians are held up as giants in civil engineering, able to build and tunnel in ways that had never been seen before, and which still provide much of our contemporary infrastructure. Their legacy can be seen in the railway networks of Great Britain, which placed difficult and challenging demands on civil engineering . As a consequence of such endeavors, Victorian times also saw the emergence of the 'celebrity' engineer. Stellar figures who first experienced the shift away from technical and site-based practices and moved instead towards the management and leadership of construction works, a professional legacy that arguably remains today. Such figures also served to further anonymise the construction workers or Navvies, who were already working in dangerous and unhealthy conditions on projects where loss of life was felt to be inevitable. Unpacking Victorian railway tunneling operations duly acknowledges the spectacular feats of engineering we have inherited from them, but also reveals how their legacy has also contributed to the ways in which we mobilise tunneling operations today. It is argued that such contributions should be recognised and consciously re-balanced if we are to take the next steps to improve tunneling operations within the profession of civil engineering today.
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Figure 1

Figure 1: British Victorian Railway Tunnels Over 2 Miles in Length (Blower, 1964)

Tunnel	Location	Tracks	Length	Built	Original Owner
Severn	Pilning	Severn Tunnel Junction	4 miles 629 yards	1873 to 1886	Gret Western Railway
Totley	Between Dore and Totley	Grindleford	3 mile 950 yards	1888 to 1893	Midland Railway
Woodford Down Line	Dunford Bridge	Woodhead	3 miles 22 yards	1838 to 1845	Sheffield, Ashton Under Lyne and Manchester Railway
Woodford Up Line	Dunford Bridge	Woodhead	3 miles 22 yards	1847 to 1852	Manchester, Sheffield and Lincolnshire Railway
Standedge North (3rd Tunnel)	Diggle	Marsden	3 miles 64 yards	1890 to 1894	London and North Western Railway
Standedge Down South (1st Tunnel)	Diggle	Marsden	3 miles 62 yards	1846 to 1849	Huddersfield and Manchester Railway and Canal Company
Standedge Up South (2nd Tunnel)	Diggle	Marsden	3 mile 62 yards	1868 to 1870	London and North Western Railway
Disley	Chinley	Cheadle Heath	2 miles 346 yards	1899 to 1901	Midland Railway
Ffestiniog	Roman Bridge	Blaenau Ffestiniog	2 miles 338 yards	1876 to 1879	London and North Western Railway
Bramhope	Horsforth	Arthington	2 miles 241 yards	1845 to 1849	Leeds and Thirsk Railway
Cowburn	Edale	Chinley	2 miles 182 yards	1888 to 1892	Midland Railway

Figure 2

Click here to download Figure Figure 2 Watford tunnel London and Birmingham Bourne102.jpg

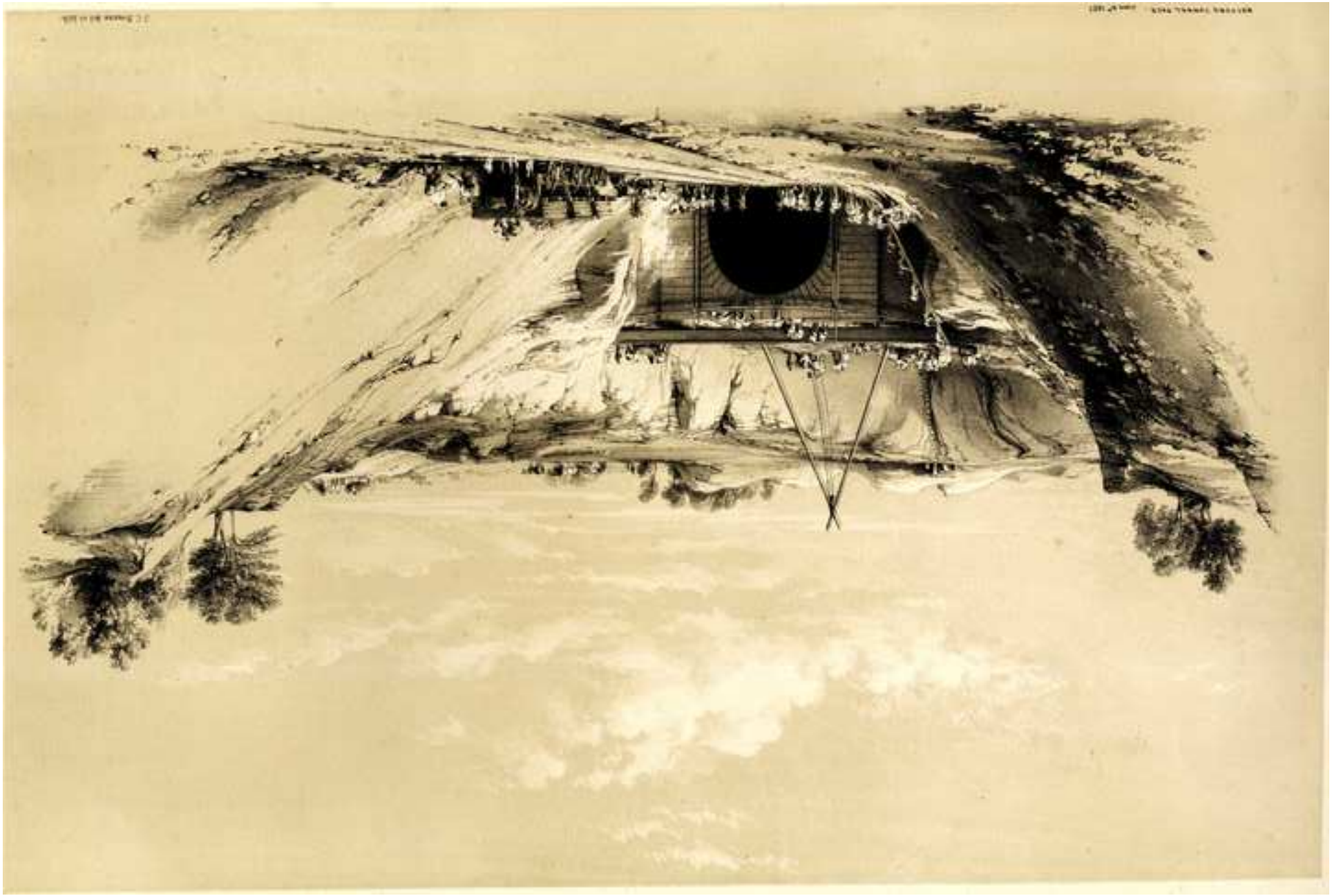

Figure 3

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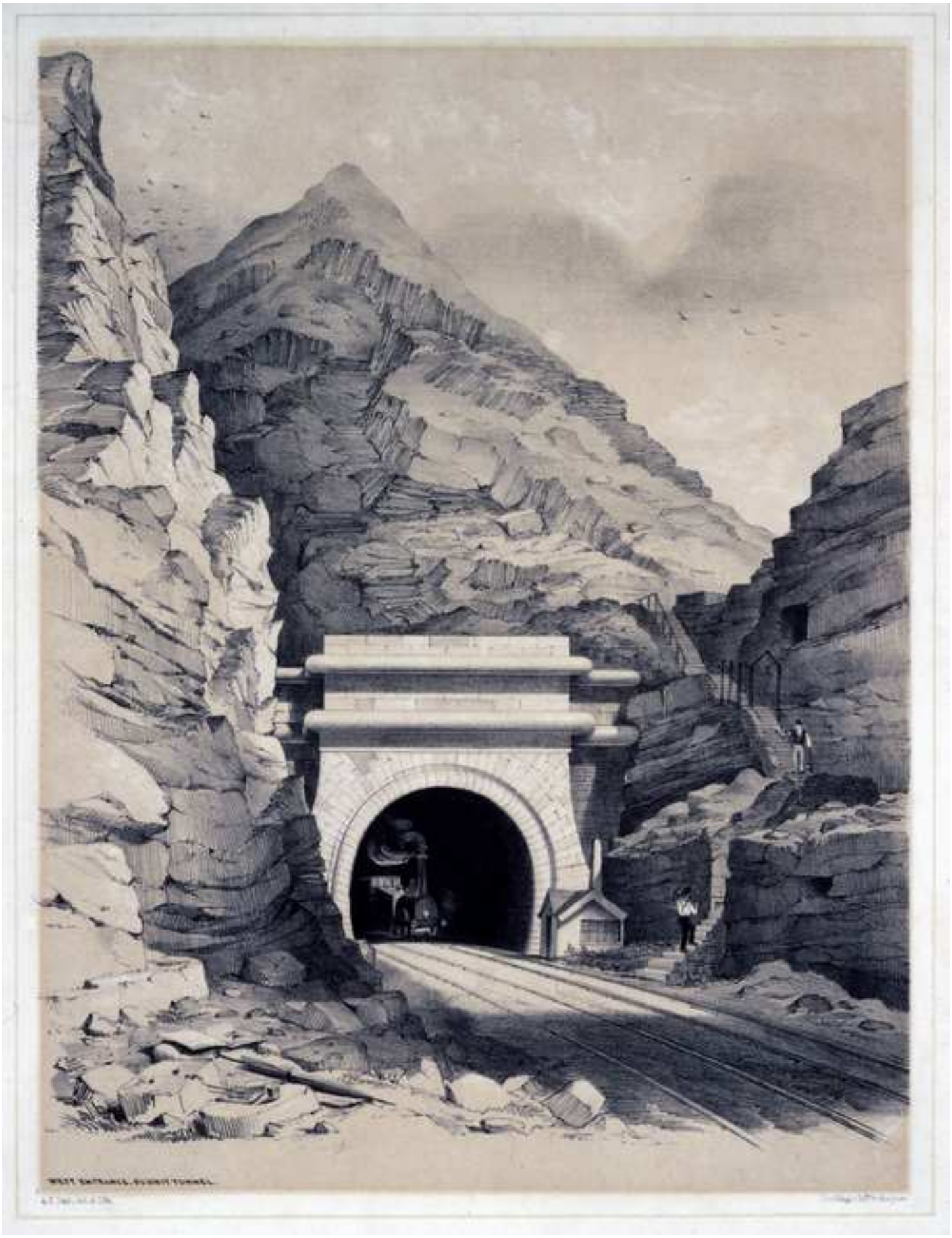

Figure 4

Click here to download Figure FIGURE 4 BOX TUNNEL.jpg

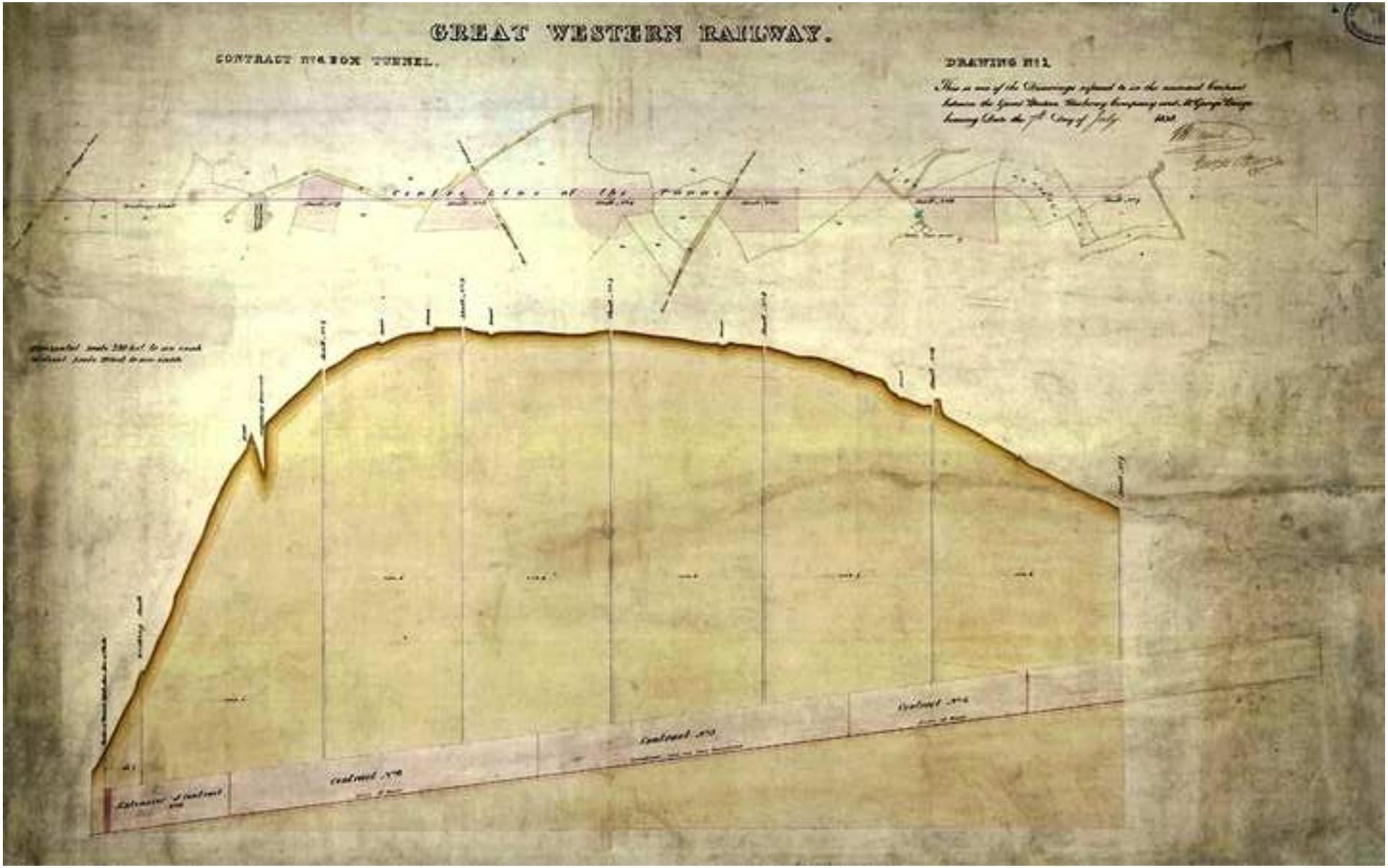

Figure 5

Click here to download Figure FIGURE 5 GRAVE STONE OF JOHN SMITH.jpg

RULES AND REGULATIONS.

1. This Fund is to be formed by subscription of Workmen employed in the construction of Blechingley Tunnel, or in connexion therewith, for their temporary relief in sickness and in case of accidents, and for the payment of Medical assistance.

2. A Committee of Management shall be appointed by Mr. F.W. Simms, the Resident Engineer; to consist of five, who shall be Masters of workmen, or Contractors of works on the Tunnel, three of whom shall be a quorum; and who shall meet once a week at least, and shall have the management of the Sick Fund, and regulate the proceedings under the superintendence of the said Mr.F. W. Simms, who is constituted Treasurer of the Fund.

3. Every man now employed, or to be employed on the works of the Tunnel, shall pay sixpence per week to the Treasurer; except in case of his having had no more than three days' employment, then he shall not be required to pay any subscription.

4. Every man must be on the books, and pay two weeks' subscriptions, before he will be entitled to any benefit from the Fund, in the event of bodily sickness; but he will immediately be entitled to the benefit of the Fund, in the event of personal injury received while in the actual execution of his work.

5. The allowance to sick members, from the Fund, shall be twelve shillings per week, exclusive of Medical attendance, in manner following.

A sick member shall be entitled to receive the full allowance for six consecutive weeks; then if the sickness should continue, he shall be entitled to half-pay for the next following three weeks, when his claim upon the Fund shall cease.

No member shall be entitled to benefit from the Fund, unless his illness or accident is certified in writing by the Medical Attendant; and if such illness or accident is, in the opinion of the Medical Attendant, or can be proved to be, to the satisfaction of the Committee, occasioned by intemperance, or any other immorality, such member shall forfeit all claim to relief in respect of such illness.

Any member receiving personal injury in the regular course of his employment upon the works of the Tunnel, or in connexion therewith, so as to incapacitate him from attending thereto, such member shall be entitled to full allowance for a period of six weeks; and then if he is unable from the above cause, to return to his work, such member shall be entitled to half-allowance for a second period of six weeks if his case requires it, when his claim upon the Fund shall cease.

Any member receiving an injury, and being removed to an Hospital, shall, while being an in-patient, receive an allowance of three shillings per week, to pay Hospital fees, &c.: but such allowance shall not exceed twelve weeks. But if he should be an out-patient, and has no other maintenance, he shall receive pay as before mentioned for members receiving personal injuries.

The Committee, with the consent of Mr. Simms, shall have power to alter the foregoing limitations of allowance in any particular case, when circumstances appear to them to require a departure from the general rule.

6. In the event of a member dying, his representatives, or those entrusted with his funeral, shall be entitled to receive the full amount that such deceased member shall have subscribed to the Fund (exclusive of the sums such member may have received during his illness) in aid towards defraying the expenses of his funeral. Any member leaving his employment, or being discharged, shall have no claim upon the Fund.

7. The Committee shall have power to increase or diminish the subscriptions of the members, and of reducing the Sick Pay, according to the state of the funds, and the claims thereupon: and shall also make and determine all contracts with the Medical Man for attendance and medicines.

All proceedings and determinations of the Committee relative to the management of this Fund must be reported to Mr. Simms, the Treasurer, and confirmed by him, before they can be acted upon; and when so confirmed shall be final.

The Committee shall prepare, for the information of the members, a Balance Sheet of the state of the affairs of the Fund once a month, or oftener if they shall be so directed by the Treasurer.

8. If at the expiration of the works on the Tunnel, or when it may be considered expedient to discontinue this Fund, there should be any funds left in hand, such funds shall be paid for the benefit of the widows and orphans of men who may have lost their life by accident on the works; and those who by accident may have been incapacitated from earning their own living: or otherwise to be given to whatever Hospital or Dispensary for the relief of the sick Poor that the Committee, with the consent of Mr. Simms, may think proper.

9. Every Master Workman, Foreman, or Ganger, must give a list of the names of the men employed by or under him, at the Tunnel Office, every Thursday evening by six o'clock, or in default thereof forfeit one shilling for the first hour, and sixpence for the second and every subsequent hour that elapses after the above time before he so delivers his list, which forfeit is to be the property of the clerk who may have been kept waiting at the office to receive the said list.

Additional Regulations made subsequently to the above.

Any sick member found drinking in a public house shall thenceforward forfeit all claim upon the sick fund, in respect of that illness.

Upon its being ascertained that any member has been, and continues to be, subject to any sickness periodically, or otherwise, the Committee to have power, at their discretion, to return to such member the full amount he may have subscribed to the Fund, during the time of his membership, and to declare him to be a member no longer.

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Title: Advancing Tunneling – the Victorian Engineering Management Legacy

Author 1

- Vikki Edmondson, BSc MEng, CEng, FICE, MIStructE, FCIHT, FIHE, FCMI, CMgr, PGCE, FHEA
- Senior Lecturer Civil Engineering, Department of Mechanical and Construction Engineering, Northumbria University, Newcastle Upon Tyne, United Kingdom
- ORCID Number 0000-0001-9982-0751

Author 2

- Dr Fred Sherratt, PhD MCIOB C.BuildE MCABE FHEA
- Senior Lecturer in Construction Management, Department of Engineering and the Built Environment, Chelmsford, United Kingdom
- ORCID Number 0000-0002-3255-7562

Author 3

- Richard Roff, CEng, FIMechE
- Group Process Safety Manager, Costain, Maidenhead, United Kingdom

Author 4

- Andy Levett, MSc
- SHE Manager, Costain, Maidenhead, United Kingdom

Full contact details of corresponding author.

Vikki Edmondson
Northumbria University
Ellison Place
Newcastle Upon Tyne
NE1 8ST
Tel 0191 349 5930
Email: vikki.edmondson@northumbria.ac.uk

Abstract (150 words)

The Victorians are often held up as giants in civil engineering, able to build, span and tunnel in ways that had never been seen before, and which still provide much of our contemporary infrastructure. Their legacy can be easily seen in the railway networks of Great Britain, which demanded some of the most difficult and challenging civil engineering ever seen. As a consequence of such endeavors, Victorian times also saw the emergence of the 'celebrity' engineer. Stellar figures who first experienced the shift away from technical and site-based practices and moved instead towards the management and leadership of construction works, a professional legacy that arguably remains today. Such figures also served to further anonymise the construction workers or Navvies, who were already working in dangerous and unhealthy conditions on projects where loss of life was felt to be inevitable. Unpacking Victorian railway tunneling operations duly acknowledges the spectacular feats of engineering we have inherited from them, but also reveals how their legacy has also contributed to the ways in which we mobilise tunneling operations today. It is argued that such contributions should be recognised and consciously re-balanced if we are to take the next steps to improve tunneling operations within the profession of civil engineering today.

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Tunnels and tunnelling, History, Failure

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1.0 Introduction

Following the feats of the Georgian civil engineers as they developed the canal network and its many tunnels across Britain (Edmondson et al 2017), came the mighty Victorians. Amongst the Victorian civil engineers are such luminaries as Rawlinson, Stephenson and Brunel, all of whom brought their professional expertise to bear on the considerable volumes of construction work undertaken during this era, and particularly the rapid growth in steam railways with the need for railway tunnels. In this paper, we explore the way the Victorian engineers looked to their work, we unpack how changes and developments of engineering practice during this time created new challenges for the profession, and we seek to illuminate how we can best recognise the learning legacy to help advance the practice of deep tunnelling operations today.

2.0 Railway Tunnelling in Victorian Britain

By the end of Queen Victoria's reign in 1901 the British Empire extended over one fifth of the world, whilst in England industrialisation and development continued apace. This was the age of steam, and the thriving years of railway construction were the 1840s, a time of dramatic and great change, with Parliament authorising approximately 8,000 miles of new line (refer to Figure 1). By the end of the age, Victorian civil engineers had constructed a total of 215 Railway tunnels (Blower 1964) on the arterial routes of the country, through a variety of different landscapes and facing many different challenges.

INSERT FIGURE 1 NEAR HERE

Most of the early railways constructed in Victorian Britain (1837 to 1901) had problems with their tunnels. At the very start of Victorian era, in February 1837, work on the 24 feet wide, 1930 yard long Watford Tunnel was finally substantially completed (refer to Figure 2). Constructed on the London to Birmingham Railway by Chief Engineer Robert Stephenson (1803 to 1859), a railway line costing at the time more than £5,000,000 (Lecount, 1839), (for comparison, during the era a labourer earned around 48d or old pence per day (Simm, 1896, p401)) the tunnel was required to avoid the estates of Lords Essex and Clarendon. An account of the Watford tunnelling work in Household Words (1856), an English weekly magazine edited by Charles Dickens, describes the likely scene as work progressed (Refer to Box 1).

'There was no day there and no peace: the shrill roar of escaping steam; the groans of mighty engines heaving ponderous loads of earth to the surface; the click-clack of lesser engines pumping dry the numerous springs by which the drift was intersected; the reverberating thunder of the small blasts of powder fired upon the mining works; the rumble of trains of trucks; the clatter of horses' feet; the clank of chains; the strain of cordage; and a myriad of other sounds, accordant and discordant. There were to be seen miners from Cornwall, drift-borers from Wales, pitmen from Staffordshire and Northumberland, engineers from Yorkshire and Lancashire, navvies — Englishmen, Scotchmen, and Irishmen — from everywhere, muck-shifters, pickmen, barrowmen, brakes-men, banksmen, drivers, gaffers, gangers, carpenters, bricklayers, labourers, and boys of all sorts, ages and sizes; some engaged upon the inverts beneath the rails, some upon the drains below these, some upon the extension of the drifts, some clearing away the falling earth, some loading it upon the trucks, some working like bees in cells building up the tunnel sides, some upon the centre turning the great arches, some stretched upon their backs putting the key-bricks to the crown — all speaking in a hundred dialects, with dangers known and unknown impending on every side; with commands and countermands echoing about through air murky with the smoke and flame of burning tar-barrels, cressets, and torches. Such was the interior of Watford tunnel."

Box 1: A Retrospective Account of Work Progressing at Watford Tunnel Appearing in Household Words (1856)

The Watford Tunnel was constructed through a soft chalk formation covered with overlying gravel. Simms (1896) reports that the chalk was deeply fissured, with fissures at times extending to a depth in excess of 100 feet. These fissures were filled with gravel, and the workers boring the tunnel encountered running gravels and sands, which would '*rush down with such violence as to plough the sides of the tunnel as if bullets had shot against it'* (Simms, 1896 p202). On the 17th July 1835 in Russell Wood, Levesdon Green (close to Watford), such an incident occurred at the base of a 90 foot, newly sunk 'gin-shaft' or header shaft . A team of five brick-layers and six labourers were completing the brick lining for the new shaft when it is believed that a member of the gang '*loosened a portion of the wood work previous to bricking the shaft'* (Anon, 1835) and triggered a sudden in rush of gravel and sand. The men in the shaft, named as '*Thomas Jordan, Joseph Barker, Thomas Evans, Silvanus Rudings, John Brett, William Byard, Thomas Windmill, James Darvell and Barlett Jeans'* (Anon, 1835) were buried alive 80 feet below the surface of the earth. It took a month for the bodies to be removed from the shaft by a team of labourers working 12hour back-to-back shift patterns. During the inquest that followed the cause of death of the men was found by the jury to be accidental. John Cropper the sub-contractor under Messrs Hardy and Copeland responsible for all the brickwork, is reported in the Buckinghamshire Herald (1835) as stating he '*had never been told the shaft was unsafe, and he never believe it to be so'.* Robert Stephenson the Chief Engineer in the same report is reputed to have stated that *'he directed in all cases in which danger was feared from the presence of sand that six feet and four feet lengths be worked. Mr Buck, the Resident Engineer, had unlimited power as to any expenses necessary to render the work safe'*, but sadly this power had not been exercised in practice.

INSERT FIGURE 2 NEAR HERE

Just over four years after the completion of Watford Tunnel, in March 1841, Thomas Longridge Gooch (1808 to 1882) completed the Summit Tunnel connecting Littleborough with Walsden in West Yorkshire (Robbins, 1984, p62). Passing beneath the Pennines on the Manchester to Leeds line at depths of between 200 to 400 feet, the 2869-yard long tunnel was, upon opening, the longest rail tunnel in Britain. Sources indicate that it took between 2 years four months and

three and a half years to construct (Robbins, 1984, p62; Anon, 1851, p20). The tunnel was constructed through shale, coal and sandstone, by a workforce comprising of on average 1000 men, 13 stationary steam engines working at the head of the shafts, and 130 horses. '*About 70 houses were erected by the company for dwellings for the work-people, who also built for themselves about 100 huts on the Summit above the tunnel' (*Anon, 1851, p20) The tunnel which was 24 feet at its widest point, was constructed by boring outwards from 14 shafts, and finished with a lining of six courses of brick set with Roman cement. Upon completion, the final arch was romantically described in a contemporary source the Parliamentary Gazetteer of England and Wales (1851, p19) - '*Amidst the piles of crags, whose face and form have been altered by the labours of man and the blasting of gun powder, rises a fine and massive arch of masonry'* (refer to Figure 3). In 1840, during construction the invert of the tunnel is reputed to have suffered a stability problem and gave way at a belt of blue shale. Although available accounts from the period do not record any casualties arising from this specific incident, during the construction of the tunnel somewhere between 28 and 41 lives are reported to have been lost (Higson, 1991; Simmons and Biddle, 2003), the variation in figures reflective of a lack of robust records from the time.

INSERT FIGURE 3 NEAR HERE

One month after the completion of the Summit Tunnel, in April 1841 Isambard Kingdom Brunel (1806 to 1859) completed construction of the 3123 yard long Box Tunnel. Situated on the line of the Great Western Railway between Swindon and Bath, this tunnel cut through oolite rock, forest marble and lias marl (refer to Figure 4). Simms (1896, p199) reports that '*eleven principal shafts, 25 feet in diameter, and four intermediate shafts, 12 feet 6 inches, were sunk for the purpose of carrying on the works of the tunnel, they averaged 200 yards apart'.* The geological conditions encountered during construction led to water ingress into the tunnel through rock fissures.

INSERT FIGURE 4 NEAR HERE

Between November 1837 and July 1838, work on the tunnel was suspended as water ingress exceeded expected volumes, filling the then complete section of the tunnel and backing up the access shafts to a height of 56 feet. A second steam pump was deployed to reduce the water level, but the difficulties encountered in the ground led to tunnelling work being behind programme. In November 1841, Brunel increased the construction workforce from 1000 to 4000 workers. The workers operated by candlelight, with the shafts acting as the only egress and ingress for all materials, spoil and the workforce in an emergency. Given the logistics and time taken to get such numbers of workers in and out of the tunnel, blasting generally occurred with the workers still in the tunnel. This management approach, coupled with water ingress caused 100 workers to lose their lives during the construction of this tunnel (Buchanan, 2003), a man for every 31.23 yards.

The collective works of Charles Dickens, whose first serial was published in 1836, the year before Queen Victoria succeeded to the throne, characterise the Victorian era as one of destitution and need, particularly for workers. Loss of life was, as the preceding accounts indicate, a frequent occurrence in construction work and in the grounds of Kirby Lonsdale Church there is a poignant example of this: a grave stone erected to a young man known by the name of John Smith, supposed to be a native of Italy, who was drowned in the River Lune August 28th 1869 aged 19 years (refer to Figure 5). The stone was erected by his fellow workmen as a token of their respect, with a telling epitaph, ‘Be ye also ready. Matt. 24, 44’.

There were some attempts at support for the workers, frequently known as Navvies, ve nmade at the time, however these were not always as philanthropic as they perhaps seem. For example, to assist with sickness as well as occasional accidents, Sick Funds could be established. However these were funded by the workers themselves, required to make a mandatory weekly payment and therefore making such funds essentially a tax on their own wellbeing. Such a mechanism also gave no incentive for engineers and managers to avoid incidents and accidents, as the costs of such events were essentially borne by the workers themselves. One such fund was established for Blechingley Tunnel, a 1327 yard long tunnel, completed in 1842 by Resident Engineer F.W.Simms. Simms includes a copy of the Sick Fund

rules and regulations in the 1844 addition of his text 'Practical Tunnelling' (refer to Box 2). The fund amongst other provision allowed a worker to receive twelve shillings per week for 6 weeks, and then half pay for the following three weeks; where a worker had been injured during a tunnelling accident half pay was extended by a further 3 weeks. If a worker suffered death then funds would be paid in lieu to his representatives to assist with the necessary funeral costs.

INSERT BOX 2 NEAR HERE

INSERT FIGURE 5 NEAR HERE

In his guide to 'Practical Tunnelling' published in 1896, Simms devotes a chapter to '*Casualties in Tunnelling',* which are attributed to '*arise chiefly form the presence of water, quick sand or treacherous materials'.* Notably, the descriptions of the casualties prepared by Simms in this account refer principally to the tunnel structures themselves, and make only limited reference to casualties amongst workers. The Sick Fund remedy was only able to make simple redress for worker injury, injury to engineering reputations and the costs for project delays was perhaps not so easily obfuscated and so merited prioritisation.

3.0 The Discourses of Victorian Civil Engineering

The Victorian civil engineers of the railways remain stellar figures in their field, their names carved deeply into the walls of the ICE's One Great George Street home. And perhaps this is rightly so; these men were able to meet the many engineering challenges of creating an infrastructure that would support Britain through the industrial revolution, enabling economic growth and prosperity that spread her empire far and wide. Yet this emergence of the Victorian civil engineering 'celebrity' also shaped the industry in ways that were ultimately deleterious to worker safety, and to an extent, this shape remains with us today: we have a more nuanced legacy to consider, and here two aspects are examined in depth. Firstly, we look at the rise of the engineering celebrity, and how it contributed to the continued anonymisation of the construction workers, which in turn led to their continued ill treatment. Secondly, the increases and changes in the pressures and challenges of such 'celebrity' roles, on the scale at which they fell to such men, also led to changes in construction management practice.

Firstly to consider the workers, the Navvies, those who actually built the railways with their muscles, their sweat and, all too frequently, their blood. In contrast to the many statues and carvings commemorating the Engineers, the lives and deaths of the railway Navvies were rarely recorded, or even reported. The work of Coleman (1965) is a notable exception that brings together myriad primary reports from contemporary times (see Ness 2009 for a more detailed examination of the 'invisible construction worker' and its repercussions for present-day practice). Yet as works of Dickens (2018) informs us, it must be recognised this was simply characteristic of the Victorian age. For example, in 1844, when arguments around health and safety legislation for factory and mill-based industries was both prominent and consistent in the House of Commons, construction was not even considered as an industry that could be improved. Rather, people were simply expected to die on construction projects, and if they became a construction worker they would readily accept that risk as part of their trade: '*There was not a great building erected, a new Reform Club, or new House of Parliament in this city, that did not occasion fatal accidents; but no one argued from that that men should not become carpenters or masons*' (Warburton, HC Deb 18 March 1844 vol 73 cc1173-267). When railway construction is specifically explored, reference to the safety or wellbeing of the Navvies or other railway construction workers is most notable by its absence. Instead, concern remains with the railway workers, those operating the railway systems, which were '…*the worst of all, the loss of life and injuries among the railway servants in all the operations connected with shunting, it amounts to a national scandal… The real point is, whether the accidents which do occur can be prevented?*' (Channing, HC Deb 19 May 1886 vol 305 cc1440-65). Whilst concern for those operating and using the railways was an ongoing subject of debate in the houses of parliament, the prevention of accidents during their construction simply does not emerge as a subject worthy of consideration.

This same discourse permeates the records of the engineers themselves. For example Thomas Longridge Gooch in his memoirs (1879) makes no mention of workers or worker fatalities, although operational incidents are acknowledged including the first passenger railway fatality of Mr Huskisson on the opening of the Liverpool and Manchester railway on the 15th September 1830. Coleman reports that Brunel, when shown a list of 131 Navvies who had been

hospitalised for serious injury on his Great Western Line, simply said '*I think it is a small list, considering the very heavy works*' (1965, p66) and that the project had involved so many men for so many years. Coleman (1965, p31) also states that '*Railway engineers rarely kept any count of the men killed. Even Robert Rawlinson of the London and Birmingham, one of the most humane of engineers, said he did not…*' This was simply the way the construction of the railways was understood and accepted at the time, and by those who had a close and immediate relationship to it: it was customary to ignore the Navvies, as if railways built themselves (Coleman 1965, p31).

Whilst the acknowledgement and recognition of such worker sacrifices has changed over the years, the shift in the dominant discourse has perhaps been slower and less significant than we would like to admit to ourselves today. Indeed, only ten years ago in the UK more than one person died per week working in construction (the figure was 77 fatalities, Health and Safety Executive 2007), and rarely were such incidents reported beyond the local press. Moreover, the reasons and explanations for such accidents can also echo from the times of the Navvies, who '*increased the ever-present hazard by their own recklessness'* and '*bravado*' (Coleman 1965, p64) as a contributory discourse of 'blaming the worker' for their own incidents also emerged, and which arguably remains with us today (Frederick and Lessin 2000). For example, Barlow (1889) justified 13 fatalities on the construction of the New Tay Bridge as being '*due in almost every case to the individual recklessness of the men themselves*' (1889) rather than any responsibility of his father who designed it, or himself, as Resident Engineer on the project.

Yet, to draw on the second dominant discourse of the time, which concerns the growing roles and responsibilities undertaken by the Victorian Engineers, an understanding of, if not forgiveness for, such attitudes and practices towards the workers can perhaps be made, and indeed may better help us understand practices today. To look to the diaries of Gooch (from 1825 onwards), the legacy of the Georgian Engineers can still be seen in the amount of time he spent '*on the line*' as an engineer, carrying out levelling and surveying and being there on his project. However, he began (from 1829 onwards) to start to spend some of his days '*in the office*' with duties such as preparing bills, estimates, making plans, measuring work, and making

pay on a fortnightly basis becoming more familiar entries in his diaries. As his celebrity increased, so did the managerial demands made on him as an engineer, as evidenced by his recollections of the Manchester and Leeds (M&L) Railway (Gooch 1879).

His involvement in this formidable project started with the considerable efforts needed to get the Bill through parliament, which clearly demonstrates the influence of both that body, and other interests, in large infrastructure construction that also remains today. In 1830 '*the Bill was lost; for the Canal interest, at that time, was very strong and powerful; and Committees of the Houses of Parliament were so open (his emphasis) to Members, that their decisions were influenced mainly by canvassing, many voting who had never heard the evidence.*' When the Bill did pass in 1835 following amendment, it was '*having to be adopted in great part in 1835 entirely from a lack of time to make any further examination*', and although the reasons for this lack of time are unclear, the lack of detail, information and even an accurate survey at the initiation of a project is perhaps another all-too familiar legacy from this time, and one unlikely to deliver project success.

Despite his satisfaction and interest in the profession of engineering, rather than enabling Gooch to focus on his self-proclaimed enjoyment of Geology, his development and progression as an engineer found him instead directed into more managerial pursuits. This included the management of the twenty four Engineering Districts that were set out along the M&L line, the success of which Gooch positions in terms of their financial resolution: *'…all of which with 2 exceptions were satisfactorily wound up and settled by myself – and those two exceptions were readily adjusted by reference to Mr Robert Stephenson as Arbitrator*'. Whilst Gooch does acknowledge the daily necessities of construction work, for example noting that the '*the average progress at each face while Tunnel in operation may be stated at 7 ½ inches a day of 24 hours. The maximum progress at a face having been about 21 inches per day of 24 hours*' this remains very much a discourse of production and progress, and Gooch seeks to praise the setting-out of his fellow engineers rather than the Navvies that put it into practice. Indeed, as found in the work of Simms, any concern regarding injury is that of a legal nature, '*The Canal and Turnpike Road interest being very hostile, the greatest care was needful to avoid injury to them*' as they

sought to sue and gain from the project as it progressed. And Gooch was certainly not unaware of this shift in his profession: '*I have often felt and said that, throughout the whole period of executing this Line, the legal difficulties occupied as much of the thought, attention and time of the Engineers as the physical; greatly embarrassing for our proceedings and adding to the expense (his emphasis)*'. Gooch also positions the financial rewards for the successful completion of this project as significant, '*with bonuses of £250 paid: upon the satisfactory completion of the contracts under their superintendence respectively; provided that the same be ready for the passage of the Trains, on or before the last day of November next...*' firmly placing time and cost together within the success of engineering practice. Gooch himself was also not immune to such incentive schemes, with '*one Thousand pounds be presented to Mr T L Gooch upon the completion of the Line*'. Yet whilst his reflections on this project, one of the most significant of his career, highlight the good work of his fellow engineers, Stephenson, the company directors and their solicitors, no mention is made at all of the workers who carried it out.

Following Gooch's success on the M&L Railway, he was in considerable demand, and as such his engineering practice became dominated by the preparation of plans for new bills, the evaluating of new projects for both colleagues and parliament, and in contractual and arbitration work. Like other 'celebrity' engineers of the time, he also made himself ill from the hours he was working, '*the chief inconvenience I felt from the excessive night and day work on these occasions was a considerable swelling in and pain in the ancles (sic).*' And he was not a wholehearted supporter of the Victorian 'Railway Mania' and was scathing of many '*projects of the most reckless character were brought forward in Parliament, and how many useless ones were sanctioned by that inefficient tribunal; a large number of them, happily, were afterwards abandoned*.'

The Gooch he presents through his writings is a man happy to style himself as one of the celebrity engineers of the Victorian age: '*I knew I was going to undertake a most difficult work in the Manchester and Leeds Railway, one which our opponents used to declare could never be executed.*' Such positioning is perhaps vulnerable to failure itself, indeed Gooch fails to mention the Summit Tunnel collapse at all within his memoirs, despite the significant loss of life incurred.

His words instead reveal a prioritisation of project management (legal and contractual) and money over buildability, technical engineering prowess or practice, and to return to our earlier discourse, most certainly over the health, safety and wellbeing of his workforce.

4.0 Key Lessons from the Victorian Engineering Legacy

During Victorian times civil engineers came into their own, creating some of the most challenging tunnels ever constructed, many of which are still in regular use today. Yet their emergence as 'Engineering Superstars' came at something of a price. Although these engineers still visited their sites, the demands of construction management were growing and the distractions of finance, cash flow management, the production pressures associated with commercial work driven by shareholders, and many legal wranglings both financial and geographical began to steal more and more of their time. The distance was increasing between those who designed and planned the work and those who carried it out, the need for more and more management creating myriad distractions from the actual goals of civil engineering. Indeed despite Gooch's desire to focus on geology and construction, as his profile grew he spent much more time in his office than outside 'on the line'.

The Victorian times arguably laid the foundations for these now-embedded structures of our industry. The greater importance given to management, contracts and shareholders seems now to be cast in stone, at the expense of the civil engineer being an active member of the site team and an inherent part of the construction work itself. Whether the presence on site of these Engineering Superstars would have reduced the accident statistics of the time will always of course remain speculative, but, if we look back to the Georgian engineering legacy, the message, in the case of tunnel construction at least, is that simply being there, being able to evaluate, reflect and act in-situ, can be of considerable benefit in the maintenance of worker health and safety.

For although the Victorian times brought the first explicit acknowledgement of worker welfare in the form of the Health and Morals of Apprentices Act 1802, this was not something that benefitted construction workers, particularly the railway Navvies. Despite the establishment of

sick funds, these were paid for by the workers and not the company management. Despite public statements of the desire to invest time and money in making the work safe, a considerable number of lives were so regularly lost that records of who and when and why simply do not exist from the time. The 'railway mania' of the mid C.19 saw the first boom in commercial rather than municipal construction projects, and the vast sums of money that could be made from such ventures left construction management and worker wellbeing as low priorities. In contemporary times we are still trying to redress this (in)balance between money and people: the construction and civil engineering industry now pro-actively seeking to prioritise and ensure the health and safety of the workforce. Whilst things are certainly different today, and there have been considerable improvements in our injury statistics, we must recognise that we are still struggling to escape the Victorian legacy that clearly positioned the commerciality of construction work as a priority over the care of the workers and the habit that experienced leaders worked remote from the construction location.

4.0 Conclusion

The Victorian legacy is one that set many of the foundation stones in the history of civil engineering as a profession. Its exploration is able to reveal the various management challenges placed on the engineering celebrities of the time as they contributed to a most turbulent industrial era, and one in which profit quickly established itself as the driving force behind many civil engineering projects. And these are challenges that remain today, and should be clearly acknowledged. Time and money remain industry priorities, and Victorian times are able to clearly demonstrate how detrimental their influence on worker wellbeing can be. The distractions of management placed on civil engineers during Victorian times are clear, and this legacy is one that has certainly endured. Indeed, the emphasis on management and leadership over technical excellence and operational involvement within the civil engineering profession remains a subject of contemporary debate within the ICE itself. Whether management of projects, contractually, legally and financially, is actually worthy of professional prioritisation, when its negative consequences can be so severe, is a challenge that clearly remains. We must recognise that perhaps the civil engineering profession should look more to the sites, to

the ground conditions and to the construction work itself, in order to ensure good tunnelling operations in practice.

The Victorians are often held up as giants in civil engineering, able to build, span and tunnel in ways that had never been seen before, and which still provide much of our contemporary infrastructure. Yet they are also able to reveal more nuanced contributions to our understandings of practice, and these should be duly recognised and consciously re-balanced if we are to take the next steps to improve tunnelling operations within the profession of civil engineering today.

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Figure captions

Figure 1. Table of Victoria British Railway Tunnels over 2 mile in Length (Blower, 1964)

BOX 1: A Retrospective Account of Work Progressing at Watford Tunnel Appearing in Household Words (1856)

Figure 2: Watford Tunnel Face (image courtesy of the Institution of Civil Engineers (ICE))

Figure 3 – Summitt Tunnel on the Manchester to Leeds Line 1844 (image courtesy of the Science and Society Picture Library)

Figure 4: Longitudinal Section of the Box Tunnel

Figure 5: Grave Stone of John Smith, Kirby Lonsdale Church.

BOX 2: Blechingley Tunnel Sick Fund Rules and Regulations Reproduced from Simms (1844 p 170-171). (Image courtesy of the Institution of Civil Engineers)